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# FieldNet: A LoRa-Powered IoT Framework for Agricultural Automation

**Parteek Singh[1], Dr.D G Bhalke[2], Dr.Smita Desai[3], Dr.Bhalke D.G.[4]**

[1]Student, [2,3,4]Professor

[1,2,3,4]Dr. D. Y. Patil Institute of Technology,Pimpri,Pune

**Abstract**

The Internet of Things (IoT) is revolutionizing modern agriculture by enabling automated monitoring and control of crops through embedded sensor networks. However, long-range communication between IoT devices remains a key challenge. LoRa (Long Range) technology has emerged as a promising solution due to its low-power, long-range (up to 10 km), and costeffective two-way communication capabilities. While LoRa offers significant advantages, its real-world performance is influenced by environmental conditions, device parameters, and network configurations. This paper introduces FieldNet, a LoRa-powered Wireless Sensor Network (WSN) framework designed for agricultural automation. FieldNet facilitates remote, low-cost monitoring and control of distributed farming systems, addressing labor-intensive and technically demanding aspects of precision agriculture. By integrating LoRa-based WSNs, the proposed system enhances scalability, energy efficiency, and real-time data acquisition for optimized crop management. Experimental evaluations assess the impact of environmental factors on communication range, providing insights into practical deployment strategies for smart farming applications.

**Keywords**— IoT, LoRa, Wireless Sensor Networks (WSN), Smart Agriculture, Precision Farming, Long-Range Communication.

## 1. Introduction

The advancement of agricultural technologies has become increasingly vital to meet the growing demand for food production and sustainable farming practices. Precision agriculture, which involves the use of technology to monitor and manage crops, has seen significant improvements with the integration of the Internet of Things (IoT). IoT-based solutions enable real-time data collection and automated control over various agricultural processes, thereby improving efficiency and reducing human labor. However, implementing such systems in rural or large-scale farms poses a number of challenges, particularly in terms of connectivity and communication range.

One of the major hurdles in deploying IoT in agriculture is ensuring reliable, long-range wireless communication between devices scattered across large areas. Traditional wireless communication technologies like Wi-Fi or Bluetooth have limited range and higher power requirements, making them unsuitable for remote agricultural applications. In this context, LoRa (Long Range) technology has emerged as a promising alternative. LoRa enables low-power, long-distance communication that can reach up to 10 kilometers in open environments.

## 2. PHYSICAL ARCHITECTURE

In this system studies in this paper,the LoRa Network consists of three main parts: A Sensor Node. A Lora TransReceiver, AN Application And Server.

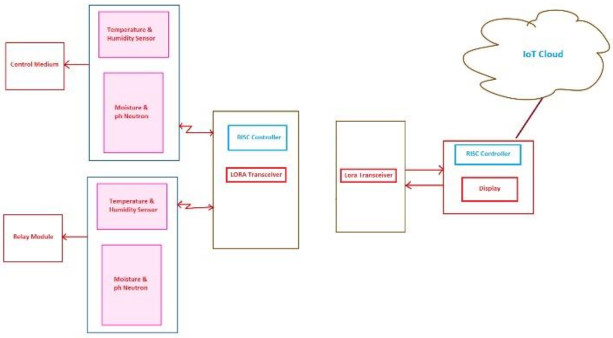



Fig 1. Block Diagram

Sensor Node-

- Collects real-time environmental data (NPK Value, soil moisture, temperature, humidity)
- Powered by batteries or solar panels for remote deployment.
- Interfaces with microcontrollers for processing.

LoRa TransReceiver-

- Responsible for long-range wireless data transmission
- Operates on sub-GHz frequency bands (433 MHz)
- Supports low-power operation to extend battery life

Application And Server-

- Stores, processes, and visualizes collected sensor data
- Provides a user interface for monitoring and control
- Implements automation rules or alerts based on thresholds

Fig 1. shows a block diagram of the proposed system. The system consists of two sensor units. Each sensor unit includes a Temperature & Humidity Sensor and a Moisture & pH Neutron. One sensor unit is connected to a Control Medium, while the other sensor unit is connected to a Relay Module. Both sensor units are interfaced with a block that contains a RISC Controller and a LORA Transceiver. These units transmit the collected sensor data wirelessly to another block that consists of a Lora Transceiver. This transceiver sends the data to a final block that includes a RISC Controller and a Display. The final block is connected to the IoT Cloud for remote monitoring and data storage.

*A.* Component Overview

RISC Microcontroller

Fig 2. RISC Board

The ESP32 is a powerful, low-cost, RISC-based microcontroller developed by Espressif Systems. Fig 2. It is widely used in IoT (Internet of Things), embedded systems, and wireless communication projects due to its dual-core processing, Wi-Fi, Bluetooth, and low-power capabilities.

1 The ESP32 uses a 32-bit RISC (Reduced Instruction Set Computing) CPU (Xtensa LX6).
2 Dual-core variant (ESP32-D0WD) allows multitasking with two cores running at up to 240 MHz.
3 Efficient power consumption, making it ideal for battery-operated IoT devices.
4 Wi-Fi (802.11 b/g/n): Supports station mode (client), access point (AP) mode, or both.
5 Bluetooth (BLE 4.2 + Classic): Enables short-range wireless communication.
6 520KB SRAM (for fast data processing).
7 448KB ROM (stores bootloader and core functions).

LoRa Module


Fig 3. LoRa Module

The LoRa SX1278 RA02 works with SPI communication protocol so it can be used with any micro microcontroller that supports SPI communication protocol. It is mandatory to use an antenna along with the module else it might damage the module permanently. The module should be powered only with 3.3V, and the operating voltage is 3.3V, and the frequency is 433 MHz and transmits and receives packets up to 256 bytes. Here we are not legally allowed to use the 433MHz frequency module for a long time other than for educational purposes.

- Frequency Range: 433MHz
- Supply voltage: 1.8~3.6V
- Standby current: 1uA
- Modulation: FSK/GFSK/MSK

- Output Power: +20dBm
- Sensitivity: -136dBm

NPK Sensor


Fig 4. NPK Sensor

- What is an NPK Sensor?

  Measures Nitrogen (N), Phosphorus (P), and Potassium (K) levels in soil. Essential for precision agriculture, hydroponics, and soil health monitoring. Works on electrochemical, optical, or capacitive sensing principles.

- Power supply: 3v to 5v
- Maximum power consumption: ≤0.15W
- Operating temperature: -40~80℃
- NPK parameters: Range: 0-1999 mg/kg(mg/L)
- Resolution: 1 mg/kg(mg/L)
- Precision: ±2%FS
- Response time: ≤1S
- Protection grade: IP68

## 3. Node & Receiver Overview

In the first node, the ESP32 microcontroller gathers environmental data by interfacing with multiple sensors and modules.

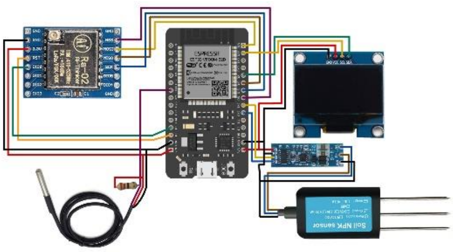


Fig 5. NODE_1

The DS18B20 temperature sensor measures soil or ambient temperature and sends digital signals to the ESP32 through a single GPIO pin, aided by a pull-up resistor to ensure stable communication. The RS485 module communicates with the Soil NPK sensor using UART protocol through the TX and RX pins of the ESP32, enabling the microcontroller to receive soil nutrient levels. The OLED display connected via I2C visually presents real-time sensor data. The LoRa Ra-02 module, which communicates with the ESP32 via SPI.

In the second node, the ESP32 also serves as the central control unit, interfacing with sensors and modules similarly to the first node.

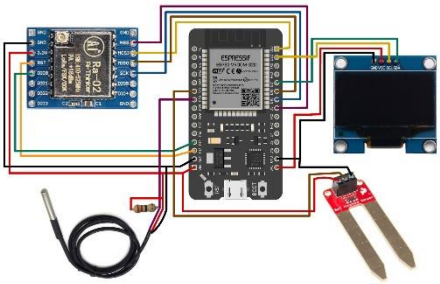


Fig 6. NODE_2

It collects temperature data from the DS18B20 sensor and soil moisture readings from the capacitive soil moisture sensor connected to an analog GPIO pin. The OLED display shows the real-time values for easy local monitoring. The LoRa Ra-02 module handles wireless data transmission using the SPI interface. This node essentially monitors soil conditions like moisture and temperature.

This node functions as a centralized station for monitoring, displaying, and logging data transmitted by multiple remote.

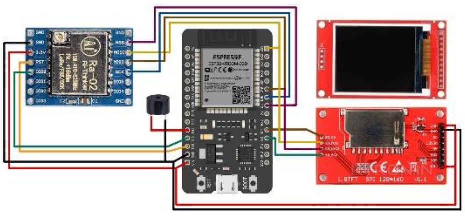


Fig 7. Transmitter-Receiver NODE

The ESP32 receives incoming data from other nodes through the LoRa Ra-02 module, which is connected via the SPI interface. This data is processed by the ESP32 and displayed on a 1.8-inch TFT screen using another set of SPI connections, with the SD card slot potentially used for logging the incoming data. A buzzer is connected to one of the GPIO pins and serves as an alert mechanism, possibly triggered by specific sensor thresholds or data anomalies.

## 4. IMPLEMENTAION DETAILS

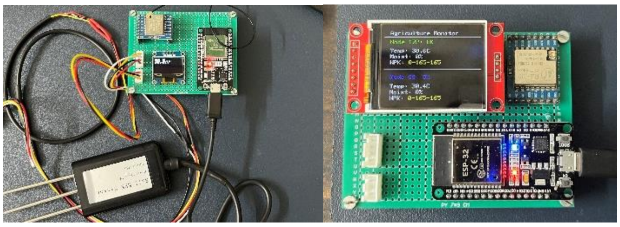
The entire implementation of the system consists of three nodes, each controlled by an ESP32 microcontroller in charge of data collection, transmission, and monitoring functions. At node one, an ESP32 connects over a single GPIO pin with a DS18B20 temperature sensor which is equipped with a pull-up resistor to allow easy communication. An RS485 module also interfaces for UART communication with a Soil NPK sensor, which allows the gathering of soil nutrient information. This data is locally displayed on an OLED screen connected via the I2C interface and is also transmitted over long-range wirelessly using a LoRa Ra-02 module connected using SPI.

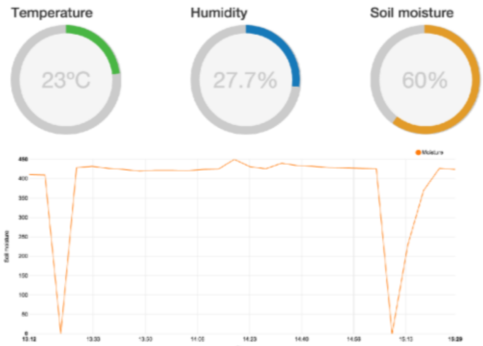
The second node is similarly structured, where the ESP32 interfaces with a DS18B20 temperature sensor and a capacitive soil moisture sensor connected to an analog GPIO pin. An OLED display depicts the information in real time while the LoRa module performs the same wireless transmission via SPI. The third node receives all sensor data from remote nodes over the LoRa Ra-02 module and processes the information through an ESP32 as the main transmitter-receiver station.The 1.8 inch TFT display, working with SPI, visualizes the data while the integrated SD card module stores the data for later analysis.

## 5. RESULTS

Real-time data acquisition and remote monitoring capabilities facilitate optimized crop management, reducing labor intensity and enabling timely interventions.

The experimental implementation confirms that FieldNet can provide scalable, cost-effective, and energy-efficient monitoring for precision agriculture.






The system's modular architecture allows easy integration of additional sensors and expansion to cover larger farming areas.

## 6. CANCLUSION

One of the primary challenges in deploying IoT solutions in agriculture is establishing reliable long-range communication across vast and often remote farm areas. Traditional wireless technologies like Wi-Fi and Bluetooth fall short due to their limited range and higher power consumption. LoRa (Long Range) technology has emerged as a promising alternative, offering low-power, long-distance communication capabilities that can extend up to 10 kilometers in open environments.

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